**Mineralogy**

# A continent in a grain of sand

*from Bruce W Sellwood*

FOR well over sixty years the abundance identities and assemblages of minerals in sandstones have been used in the determination of sediment provenance in order to reconstruct the geography climate and geology of sediment source terrains of the past. Recently, it has been realized that sandstone composition is to a large degree also governed by plate tectonics. Provenance studies of modern sedimentary systems have previously been carried out on the scale of individual basins, but not for a whole continent. Now on page 645 of this issue, Potter describes the mineralogy of sands from the beaches of South America, and interprets it in terms of the palaeotectonics of the continent.

In ancient systems, the petrography of sandstones has been used in the interpretation of the geotectonic regimes of depositional basins, such as a passive continental margin or a fore-arc basin, and of source areas, despite the fact that sand is recycled from older sandstones. Geotectonic interpretations rely heavily on observations and assumptions of the probable composition of typical terrestrial terrains. It is argued that quartz-rich sediments are associated typically with passive continental margins and that quartz-poor sediments are mostly of volcanic origin in magmatic arcs. Sediments of intermediate quartz content are generally believed to be associated with active continental margins and orogenic belts while arkosic (feldspar-rich) sands are often derived from uplifted basement rocks adjacent to rifts and wrench faults. Other factors, such as climate and the length and vigour of streams, are considered to tune the ultimate composition of deposited sands.

The validity of these palaeotectonic models can be tested only in terms of large-scale modern investigations and this is the significance of Potter's study. He chose South America because it has a well-developed active margin on its west coast, a passive margin on its east coast, with transcurrent motions affecting only the Caribbean border zones. Although lacking significant continental glaciation it exhibits major climatic belts lying transverse to the Andes. Potter's is the first report on the petrography of sands from within the same environmental regime (beaches) around an entire continent and thus is highly significant, even though the results come from only about 200 samples.

Much of the sediment arriving on continental beaches is derived from rivers and Potter argues that its mineralogy is likely to have been extensively modified by abrasion. Furthermore, if the mineralogy of beach sands closely relates to the tectonic setting of adjacent land areas, then that of the local river sediments is likely to be even more closely related. The results of the study confirm the predictions of earlier workers (for example, Dickinson, W F R. & Suczek, C.A. *Bull. Am. Ass. petrol. Geol.* **63**, 2164; 1979). On its leading margin (the Pacific coast) quartz comprises only 19 per cent of the mineral and so is subordinate to rock fragments and feldspar while on the trailing margin (Atlantic coast) it comprises, on average, 96 per cent of the mineral, even where mountains of Precambrian crystalline rocks border the coastline.

Some anomalous patterns exist, however indicating that results from ancient sequences must be interpreted with some caution. Although sited on a trailing margin, the Argentine coast from Rio de la Plata to Tierra del Fuego has an Andean (leading-margin) composition being dominated by volcanic rock fragments. This is partly because Patagonia is too narrow to allow abrasive processes to be completed and partly because the coastal bedrock is itself immature young sediments recently derived from the rising Andes.

This work thus confirms the view that the detrital mineralogy of ancient sandstones may be used successfully in the reconstruction of palaeoplate settings.

Although the predicted patterns of mineralogical provinces are generally confirmed in the study further questions need to be answered. For example, what subtle effects does climate have on the rate of degradation of certain types of rock and mineral species during transport? In what way does the interaction between relief transport distance and rainfall favour either the elimination or preservation of unstable grains? And to what extent do the boundaries between mineralogical provinces coincide with major physiographical features such as large river mouths?

Potter's study is merely a first step, doing for grains on a continental scale what clay mineralogists have already done for mudrocks on a global scale (Griffin, G.M. Windom, H & Goldberg, E.D. *Deep Sea Res.* **15**, 433; 1968). As Potter observes, if his models stand up to further scrutiny, the next stage will be deduction of sand composition over all types of environment of an entire continent (or palaeocontinent). Because the depositional maturity of sediments is a key factor in their behaviour during burial, predictive models based on studies such as Potter's bear directly on the assessment of regional porosity and permeability trends in hydrocarbon reservoir rocks. □

*Bruce W Sellwood is a Lecturer in Geology at the University of Reading, Whiteknights, Reading RG6 2AB.*

**Astronomy**

# Nemesis for Nemesis?

*from Mark E. Bailey*

LAST spring, great interest and excitement were generated by the idea that a hypothetical companion star of the Sun, called Nemesis by some, could trigger the periodic sequence of extinction events found in the fossil record[1-5]. Now, only six months later another collection of papers on the same subject (see pages 635-642) gives what amounts to a considered reflection on the model.

Interest in Nemesis began about a year ago[4] following the claim by Raup and Sepkoski to have identified a regular 26-Myr periodicity in the fossil record, with a confidence level of better than 99 per cent. The evidence that the sequence of events was periodic was further strengthened by an independent analysis of the cratering record[3] which produced a period and phase for the cyclicity agreeing with that of the fossil record. These arguments for strict periodicity in the geological record can be challenged at a number of points[5] although the independent evidence for rough periodicity as, for example, in the sense that the solar sunspot cycle is 'periodic' is probably less easily denied[6-8].

But if the cratering and extinction record is strictly periodic, which will be settled only by further detailed research on the geological front, it is clearly important to devise explanations, and this is the spirit in which the Nemesis proposal was made. Thus, it was argued, the orbital period of the hypothetical companion should give the strict periodicity required, while its gravitational influence on the comets in a hypothetical dense inner core of the Oort cloud might produce periodic comet showers in the manner outlined by Hills[9]. The further possibility that Nemesis (or Planet X) might show up in the Infrared Astronomical Satellite data also gave piquancy and a certain urgency to the debate.

In the papers published in this issue of *Nature*, the Nemesis proposal is extended and shown, in fact, to be quite incapable of producing the strictly periodic sequence of extinction events for which it was originally designed. The stability of the orbit has been investigated by Torbett and Smoluchowski[10] whereas Hills[11] and Hut[12] show in particular that when stellar pertur-

bations and the overall tidal field of the Galaxy are included, the orbital period should drift towards larger values by about 15 per cent or more over the 250-Myr time scale considered by Raup and Sepkoski. The probably dominant effects of giant molecular cloud perturbations would further reinforce this conclusion, and cast serious doubt on the likely survival of such a solar companion for the age of the Solar System[10,13]. Of course, it is conceivable that the star might have been recently captured or scattered to its present orbit from a more tightly bound state with much shorter period, but these suggestions beg many questions. In any case, as shown by Hut[12] it appears that the Nemesis proposal if correct does not predict a constant interval between extinctions. A re-analysis of the fossil record may agree with this new prediction[2] but this has not yet been carried out.

The alternative, that extinctions are quasi-periodic, was explored last April in two papers[14,15] and is now reviewed in detail by Clube and Napier[3] who argue strongly against the Nemesis proposal and come down in favour of a galactic connection, as they have advocated for some time[6–10].

In view of these developments, one might possibly be excused for regarding this episode of hypothesis followed by near-retraction as yet another example of the explosion in the volume of the literature, and of the over-rapid publication of speculative ideas. Previous commentaries[4,5] already hinted at this, and it is therefore perhaps not wholly out of place to consider the point further. Although some cynicism is doubtless justified and can easily be understood, to hold such a view exclusively is, in my opinion, to miss the point. It is often the case in astronomy, and no doubt other subjects, that the various pieces of a puzzle can be assembled in a number of ways and still explain the same data. Indeed, it is an important part of a theorist's job to do just that, and provided the proposed hypotheses take all the facts into account and are not obviously so contrived as to be subject to Occam's razor the more possibilities the better. This in spite of the reality that no more than one can be true. Science often progress by mistakes and it is therefore too easy simply to dismiss speculative suggestions as a kind of non-science.

In the present case, the argument for Nemesis causing mass extinctions is indeed highly speculative since it assumes the existence of the star the presence of a dense inner core to the Oort cloud, the regularity of the extinction cycles and the possibility that impacts trigger extinctions. Yet whatever the final decision about the existence of the star the benefits of the suggestion have already outweighed any temporary nuisance or adverse reaction it may originally have caused. For example, the shape of the Oort cloud and the stability of comet-like orbits under the perturbing action of passing stars, gas clouds and the Galaxy are crucial to an understanding of cometary origins. Moreover the papers now published have a clear connection with studies of binary stars and of their long-term orbital stability while the connection between these kinds of problem and studies of open star clusters has already been noted[17].

On the geological front I am less qualified to judge, but if the Nemesis saga has served only to increase general awareness that cometary impacts may frequently occur then it will have been beneficial. Ten years ago the idea was hardly considered, and even last year at the Brighton meeting of the British Association for the Advancement of Science, it was dismissed. Yet the most conservative Oort cloud model predicts some cometary impacts, and presumably they do have some influence worth exploring.

Finally if the extinction sequences should somehow be shown to be strictly periodic, it may be worth noting that there is already a new variant on the Nemesis theme[18] — in which comet showers are still predicted to be periodic. To mix two metaphors, though there may be smoke without fire, perhaps even the darkest clouds have silver linings.


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*Mark Bailey is in the Department of Astronomy, University of Manchester, Manchester M13 9PL.*

**Behavioural ecology**

# Optimal foraging theory tested

*from Jared M. Diamond*

A KEY postulate of behavioural ecology is that animals practise 'optimal foraging'. That is, animals forage for food in a way that maximizes some function such as the rate of energy gain[1,2]. A paper by Carpenter *et al.* describes an ingenious experiment designed to test the theory of optimal foraging[3].

Consider the territory size of an animal attempting to maximize its daily net energy gain. Optimal foraging theory argues that a territory yields benefits (especially food resources), which increase in proportion to territory size up to a ceiling set by an individual's food-processing abilities or time constraints. An increase in territory size also incurs increased costs of travel time and territorial defence against intruders. Supposedly individual energy-maximizing animals can both assess and achieve an optimal territory size at which the difference between the benefits and costs represents a maximal rate of energy intake.

While much animal behaviour is roughly consistent with this view, it has proved very difficult to devise quantitative tests of the optimality principle in the field. A suitable test would require measuring an animal's rate of net energy intake (approximated by its rate of weight gain) as a function of the parameter putatively optimized (for example, territory size). One could then examine whether the rate of weight gain does peak at intermediate territory sizes, and whether individuals adjust territory size towards this optimal value.

How could one perform such a test? Periodically capturing a wild animal to weigh it has the obvious drawbacks that one can rarely count on capturing an individual at fixed intervals, and the disturbance associated with capture is likely to influence the results. The ideal solution would be to induce an animal to weigh itself repeatedly. It is this task of persuasion that has recently been achieved by F. Lynn Carpenter, David C. Paton and Mark A. Hixon, working with rufous hummingbirds (*Selasphorus rufus*) of western North America[3].

Like most other migratory hummingbird species, the rufous faces severe energetics problems. In July and August of each year the birds migrate at least 3,000 km south, along mountain ranges, from their breeding grounds (Oregon to Alaska) to their wintering grounds in southern Mexico[4]. To fuel their flight, these 3-g birds stop en route, defend feeding territories and gain at least 1.5 g of fat in 1–2 weeks before resuming migration. At this season, migration in the mountains is risky: rain, hail and wind often prevent feeding, destroy the flowers that serve as nectar sources and even endanger the birds themselves. Thus, individuals should be selected to make few stops, and to fatten up quickly and maximize daily net energy gain while on stopover so as to complete the migration as quickly as possible.

In order to obtain exclusive access to the nectar of flowers[5,6] hummingbirds engage in two types of fierce competition for territories. First, territory-owning hummingbirds spend much time and energy driving off intruding hummingbirds and sometimes bees, hawkmoths and